Does the hemispheric energy balance set the mean location of ITCZ?
or
What role plays the cross-equatorial ocean heat transport?

Authors: M. Z. Hakuba[1,2], G. L. Stephens[2,3], T. Lee[1], A. D. Rapp[4], M. A. Balmaseda[5]

[1] Colorado State University, Ft Collins, USA, [2] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA, [3] University of Reading, UK, [4] Texas A&M University, College Station, USA, [5] ECMWF, Reading, UK

Background & Objectives

- Stephens et al. 2016 established the hemispheric energy balance (HEB, 2005-2015, Figure 1) from the ocean perspective, in which observed ocean heat content changes (Fig. 2) and ocean heat transport (Fig. 3) provide the surface constraints and CERES EBAF the TOA radiative fluxes.
- The HEB implies that heat has to be moved across the equator to the NH. This is largely facilitated by the oceans and partly compensated by a slight southward heat transport in the atmosphere.
- Previous studies suggest this setup requires the ITCZ to be slightly North of the equator (Figure 4), pushed there by the oceanic MOC that transports heat from the SH to the NH.
- Here, we study the role of the cross-equatorial ocean heat transport (CHT) in setting the location of the ITCZ, using ocean reanalysis data of CHT and surface net heat flux (Q) in the Atlantic and Pacific. The monthly mean location of the ITCZ we estimate from MERRA-2 near-surface wind divergence.

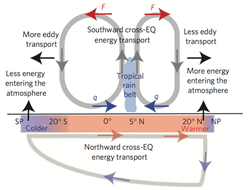


Figure 4: Role of the oceanic MOC in forcing the NH maximum of tropical precipitation (Frierson et al., 2013)

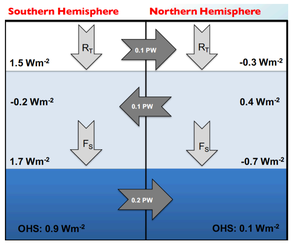


Figure 1: Hemispheric energy balance (Stephens et al., 2016)

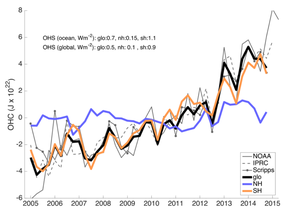


Fig. 2: Seasonal anomalies of ocean heat content for the global mean, SH and NH. Sources in legend.

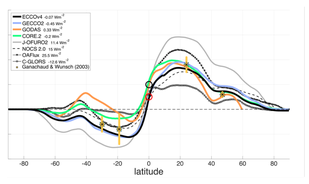
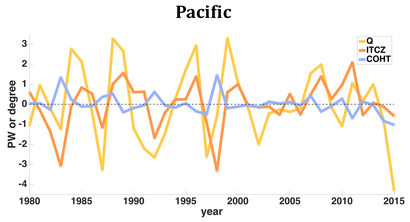


Fig. 3: Meridional ocean heat transport (PW) from zonally integrated surface net heat flux taken from eight different ocean reanalysis and observations.

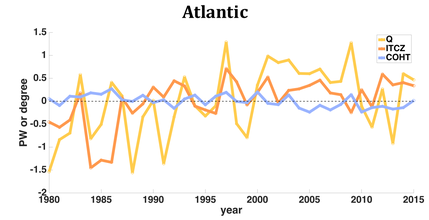
Results & Discussion



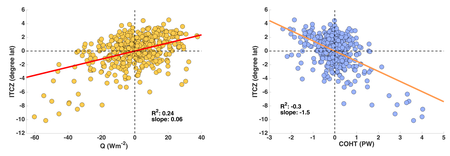
Inter-annual co-variability

Annual anomalies of net heat flux into the ocean (Q, 5*Wm^{-2}), ITCZ location (º latitude), and ocean cross-equator heat transport (COHT, PW)

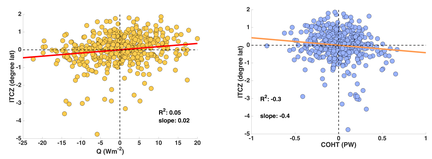
- Pacific: larger amplitude in all quantities: ENSO, shallower overturning. Atlantic: COHT driven by AMOC.
- In both oceans, ITCZ position somewhat correlates with Q & anti-correlates with COHT (see below).



Relationship COHT – Q – ITCZ



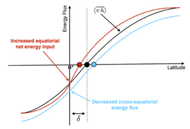
Scatter plots of monthly anomalies of ITCZ location vs. Q and vs. COHT, with regression slopes and R^2 coefficients.



Hypothesis: energy flux equator

Location of ITCZ = energy flux equator (CHT in **atmosphere**=0) driven by equatorial energy input (NETA) and CHT in **atmosphere**

LAT of ITCZ ~ CAHT/NETA

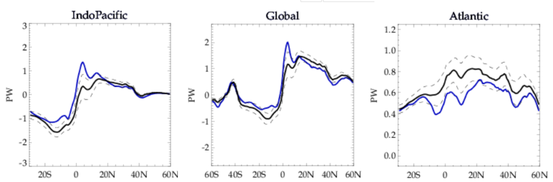


"ITCZ position is proportional to the strength of the atmospheric CHT and inversely proportional to the equatorial net energy input into atmosphere (Bischoff and Schneider 2014; Schneider et al. 2014).

- **The equivalent for the ocean: ITCZ position proportional to equatorial net energy input into ocean and inversely proportional to ocean CHT!**
- **ITCZ location dominated by CHT variations (Pacific)?**
- **What are the mechanisms? Impact on SST gradients?**

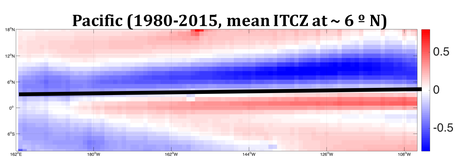
Methods

- ORAS4, ECMWF ocean reanalysis provides ocean heat transport per basin and gridded surface net heat flux



- Next step: Same analysis with ECCOv4 (JPL ocean model solution) to get independent estimates

- ITCZ mean location in º latitude, where wind divergence minimizes in respective ocean basin:



- Next step: ITCZ location from detection algorithm by Wodzicki & Rapp (2016): ERAI + GPCP & TRMM

Conclusions

- Current hemispheric energy balance suggests slight surplus of energy absorbed in the SH, implying that heat has to be moved northward across the equator. This is facilitated by the ocean and partly compensated by a southward CHT in the atmosphere.
- Previous studies suggest this setup requires the ITCZ to be displaced slightly North of the equator to move heat towards to the SH (Figure 4). The northward ocean CHT thereby drives the circulation.
- This would suggest that the location of ITCZ and COHT are proportional (correlated). However, we show that on inter-annual and seasonal scales that the ITCZ and COHT are anti-correlated.
- Long-term global mean (~0.2 PW) & Atlantic (~0.8) mean COHT are northward in line with the northerly ITCZ, unlike Indo-Pacific (-0.5 PW).
- Hypotheses of 'energy flux equator' wrt. to ocean data results in opposite relationships between energy input, CHT and ITCZ location
- The HEB & ocean's role in setting the ITCZ position is not understood well. Further research on the impact of ocean heat uptake and heat transport on SST and tropical convection is strongly encouraged.

References

- Stephens et al. (2016): The Curious Nature of the Hemispheric Symmetry of the Earth's Water and Energy Balances, CCCR, 2 (4).
- Frierson et al. (2013): Contribution of ocean overturning circulation to tropical rainfall peak in the Northern Hemisphere, Nature Geo, 6.
- Wodzicki & Rapp (2016): **Long-term characterization of the Pacific ITCZ using TRMM, GPCP, and ERA-Interim, JGR, 121.**
- Bischoff & Schneider (2014): Energetic Constraints on the Position of the Intertropical Convergence Zone, Jclim, 27.
- Schneider et al. (2014): Migrations and dynamics of the intertropical convergence zone, Nature, 513.

Acknowledgments

Many different sources of data were used in this study and we gratefully acknowledge all of the institutions and research groups providing data and guidance. This work was supported under NASA Grants NNN13D984T and NNN12AA01C.

Contact: maria.z.hakuba@jpl.nasa.gov